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CORRESPONDENCE

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Continuous Mechanical Chest Compressions During Cardiac Arrest to Facilitate Restoration of Coronary Circulation With Percutaneous Coronary Intervention

To the Editor: Sudden cardiac death is a leading cause of death worldwide often due to ventricular fibrillation (VF) preceded by an ischemic event (1). Survival rates remain poor (2). Advanced cardiac life support (ACLS) with manual chest compressions are often insufficient (3), which may limit return of spontaneous circulation (ROSC). Mechanical chest compression devices such as the European Conformity-approved LUCAS device (Jolife, Lund, Sweden) has shown encouraging results in its feasibility for application during cardiac arrest (4).

Early percutaneous coronary intervention (PCI) has revolutionized treatment of acute ST-segment elevation myocardial infarction (MI). An early revascularization strategy would, therefore, seem reasonable, if ischemia is suspected, in a cardiac arrested patient with prolonged unsuccessful ACLS.

We present 2 case reports of mechanical chest compressions combined with angiography and PCI, followed by a methodological study in pigs. The aim of the animal study was to document the applicability of performing PCI during uninterrupted chest compressions with LUCAS.

A 53-year-old man suffered paramedic-witnessed VF cardiac arrest after some days with chest pain suspicious of MI. Advanced cardiac life support was started immediately but multiple defibrillation attempts (LIFEPAK 12, PhysioControl, Redmond, Washington) were unsuccessful. Uninterrupted mechanical chest compressions with LUCAS were initiated, and the patient awoke and needed sedation to continue treatment with LUCAS. During a short period of ROSC, electrocardiogram (ECG) showed signs of ST-segment elevation MI. Sustained ROSC was not achieved, and transport to the hospital was established. Due to procedural discussions in the emergency department, transport to the angiographic laboratory was delayed, and his occluded left anterior descending artery (LAD) was revascularized 110 min after his cardiac arrest. Pump function never recovered, and this was later confirmed by echocardiography. Circulation was maintained with LUCAS only, and 6 h after the cardiac arrest, LUCAS was discontinued and the patient died.

Coronary angiography was performed in a 53-year-old woman with suspected coronary heart disease. Two-vessel disease was documented, and PCI was performed on both arteries en suite. Immediately after PCI, she collapsed in cardiac arrest with pulseless electric activity, and ACLS was initiated. Return of spontaneous circulation was not achieved despite numerous defibrillation attempts due to VF. After approximately 10 min, LUCAS was applied, and a reangiography confirmed reduced flow in LAD. Antiplatelet therapy was administered, and PCI of LAD was performed. After 70 min with LUCAS, stable ROSC was achieved. Subsequent postresuscitation care included intra-aortic balloon pump and therapeutic hypothermia. The patient was discharged neurologically intact, and has today a 100% working capacity.

Animal maintenance and housing were in accordance with the National Institutes of Health Publication Number 85-23, revised 1996. The local laboratory animal ethics committee approved the protocol. Five pigs weighing 29 ± 3 kg were anesthetized with 30 mg/kg^{-1} ketamine and 1 mg atropine intramuscularly in the pen. Propofol intravenously maintained anesthesia throughout the experiment. The pigs were tracheally intubated and mechanically ventilated (Oxylog 2000, Drägerwerk Aktiengesellscaft, Lübeck, Germany) with ambient air at 15 breath/min^{-1} with adequate tidal volumes, controlled by the gas monitor (Datex Capnomac Ultima, Helsinki, Finland). The pigs were placed on a stable position on the angiograhic table, and LUCAS was attached.

Ventricular fibrillation was induced by applying 9-V AC current intrathoracically. Continuous mechanical chest compressions with LUCAS were started in an anterior-posterior position (Fig. 1) at a rate of 100 min^{-1} with a compression depth of 5 cm. Ventilation was performed manually with 100% oxygen with a self-inflating bag, 10 breaths/min^{-1}. After 5 min of continuous cardiopulmonary resuscitation (CPR), a cut down was performed on the right femoral artery. The pigs were randomized to having a simulated

Figure 1 **The Practical Setup on the Angiographic Table Demonstrated on a Mannequin**

The mechanical chest compression device LUCAS (Jolife, Lund, Sweden) in its anterior-posterior position on the chest allows oblique views (from both sides) for visualization of coronary arteries and subsequent percutaneous coronary intervention during uninterrupted mechanical chest compressions.

Table 1 Time Intervals and Outcome Data From Each Pig and Mean MAP (± SD) Within Each Pig During the Procedure

Pig No.	Time From VF to Balloon in IRA (min:s)	Time From VF to ROSC (min:s)	Mean MAP (± SD) During the Procedure (mm Hg)	ROSC
1	18:27	20:46	57 ± 16	Yes
2	10:35	N/A	33 ± 1	No
3	10:15	14:00	35 ± 0	Yes
4	10:02	12:40	51 ± 11	Yes
5	10:45	11:20	56 ± 11	Yes

IRA = infarct-related artery; MAP = middle arterial pressure; N/A = not applicable; ROSC = return of spontaneous circulation; SD = standard deviation; VF = ventricular fibrillation.

left (n = 2) or right (n = 3) coronary artery infarction. The noninfarct-related artery was first catheterized, subsequently the infarct-related artery was visualized, followed by balloon inflation to simulate the revascularization procedure. Three DC shocks maximum were given in an attempt to achieve ROSC, no further ACLS was provided. Return of spontaneous circulation was defined as stable circulation with a middle arterial pressure (MAP) >50 mm Hg after 5 min. The pigs were monitored with ECG, and the MAP was obtained through the angiography catheter. Finally the pigs were euthanized.

Coronary angiography and PCI were possible without interrupting chest compressions with LUCAS except for a 10-s period in the first pig due to intubation problems of the left coronary artery. Individual results are presented in Table 1. The practical setup is illustrated in Figure 1. LUCAS occupies the space above the middle of the chest allowing only oblique angiographic projections.

Continuous mechanical chest compressions with LUCAS during cardiac arrest in both pigs and humans enabled adequate hemodynamics and assessment of the coronary circulation.

Acute MI is the single most common cause of cardiac arrest (1,2), and PCI after ROSC is well accepted (5). Successful treatment with PCI during cardiac arrest and manually interrupted CPR has previously been presented (6). Our case reports both show the practicable use of uninterrupted mechanical chest compressions during the angiography procedure, and the possibility of successful survival, even after prolonged ACLS (Case 2). In case 1 the circulation with LUCAS was adequate for the patient to wake up and require sedation, and it appears possible to "buy time" before final, decisive treatment. However, our 2 case reports demonstrate that the final outcome is dependent on the time interval from cardiac arrest or start of infarct development until balloon inflation.

The uninterrupted mechanical chest compressions with LUCAS did not inhibit visualization of the coronary arteries and the PCI procedure, but, due to the position of the LUCAS, only oblique angiographic projections enabled visualization of the coronaries.

If a stable ROSC is not achievable after ACLS, this procedure may be an alternative approach for at least 2 circumstances:

1. Cardiac arrest occurring during the PCI procedure.
2. Other cardiac arrests with suspicion of MI, if patients can be brought within a short time to the angiographic laboratory with uninterrupted mechanical chest compressions.

The experimental part was a methodological feasibility study. LUCAS is designed for adult human beings, not for 30-kg pigs, and inadequate placement would result in suboptimal compressions, which may explain worse hemodynamics in 2 pigs and no ROSC in 1 pig. We used blankets to increase the contact area between the pig and LUCAS. Although the procedure was successful in the 2 case reports and the pigs, the results should not be generalized for humans in emergency cases.

Continuous mechanical chest compressions with LUCAS during cardiac arrest enabled assessment of the coronary circulation and the potential for PCI in an attempt to restore coronary circulation. Further clinical studies are required.

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